ON THE EARLIER VOLCANIC ROCKS OF THE PAPAL STATES, AND THE ADJACENT...

Roderick Impey Murchison

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ON THE EARLIER VOLCANIC ROCKS OF THE PAPAL STATES, AND THE ADJACENT PARTS OF ITALY.

By Sir RODERICK IMPEY MURCHISON,

G.C. ST. S., V.P.G.S., ETC. ETC.

[*From the* Quarterly Journal of the Geological Society of London
for August 1850, Vol. VI.]

Introduction.—During a winter's residence in Rome, including journeys to and from that city by the Maremma, Siena, and Viterbo on the west, and by Perugia on the east, together with excursions, including one to Naples, in the spring, the abundant "earlier volcanic" products of that region were necessarily brought under my notice. For, although my chief object in visiting the peninsula was to ascertain the order of succession from its secondary to its tertiary strata, the very existence of those formations, particularly of the latter, was so intimately connected with contemporaneous or subsequent eruptions of volcanic matter, that it was impossible for any geologist not to be alive to the importance of observations which tended to throw light on the conditions under which such igneous operations took place. I had moreover a strong additional motive to enter into this branch of our subject, from habitual intercourse with my friend, the accomplished mineralogist, Count L. Medici Spada*, and his zoological coadjutor Professor Ponzi.

Although all the materials prepared by these authors will, I trust, at no distant day be published†, still as they will even then appear in a foreign language, and will imbody local phænomena not requisite for the clear comprehension of the subject, I venture to offer the present sketch, which, although in part derived from the labours of my above-mentioned friends, contains a modification of their views concerning the Latian Hills, which I consider to be of some importance‡.

Not entering fully into the details of the literature of this subject, I may briefly observe, that, among the writers who have treated of the subsoil of Rome, Brocchi was the first modern who gave it a specific geological character. Whatever errors his work, entitled 'Suolo di Roma,' may have contained, have been corrected to a great extent by Leopold von Buch, Lyell, Hoffman, Pareto, and other authors. Still, looking at the only geological map of Italy yet published, the value of the distinction which is advocated in this memoir will at once be seen. For in that very useful map, the author, M. Collegno, has not attempted to separate the oldest trachytes and basalts, associated with the subapennine strata and obviously of subaqueous origin, from modern volcanos; so that the Euganean Hills and

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* At that time Monsignore Medici Spada.

† Monsignore Medici Spada was preparing for my use a descriptive memoir in Italian, which it was my intention to have had translated into English, when the political agitation to which Rome became subject suppressed every spark of scientific energy. Still, before I left that city, I was fortunate enough to induce Professor Ponzi to lay aside his military uniform and accompany me over the Latian volcanos, of which he prepared an instructive map, of which the diagram, fig. 3, p. 285, is a reduction, accompanied by sections.

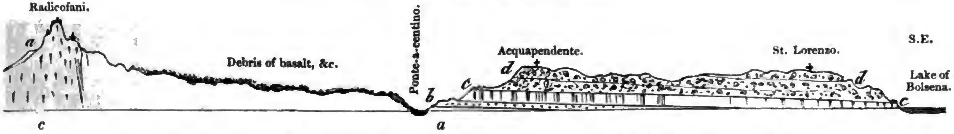
‡ Since these pages were written, Professor Ponzi has published a memoir, entitled "Osservazioni Geologiche lungo la Valle Latina," Roma, 1849, in which he shows the existence of volcanic rocks, of the same age as those of Hannibal's Camp, at Tichiena and Posi, near Frosinone. I cannot agree with my friend, when he places the Macigno between the hippurite limestone and the nummulite rocks, nor do I admit that there is any geological distinction between the cretaceous limestone of the Volscian Hills and that of the Sabine Hills. (See my former Section, Quart. Jour. Geol. Soc. vol. v. p. 281, fig. 35.)

Radicofani are represented under the same colours as Etna and Vesuvius.

Tracts north of Rome.—No geologist can travel from Radicofani to Rome, nor examine the Campagna di Roma, properly so called, in any direction, without being satisfied that the region is eminently one of volcanic character. He sees around him numerous crateriform cavities, evincing the former action of fire; but when he more closely examines them, he has little difficulty in perceiving, that although volcanic in a general sense, they are distinct from the craters of Central France, for example, or of any other region in which atmospheric or subaërial volcanos have operated. In the Campagna there is no trace of the broken-down side of a crater, and still less of any currents of subaërial lava which flowed from such depressions, like those which so decisively demonstrate the origin of the currents or "cheires" of Auvergne. On the contrary, all the stratified accumulations of basaltic rocks, tufa, sand, lapilli, puzzuolana, travertine, or gravel, indicate most clearly that they have all been formed or rolled under *water*. Among the oldest, and at the same time the most crystalline of these rocks, is the basaltiform felspathic greystone with quartz crystals of iolite or prismatic quartz, the tephrine lava of Brongniart, which occupies the rugged hill of Radicofani, about 2470 French feet above the sea, and a few miles only to the east of the higher trachytic mountain of Amiata.

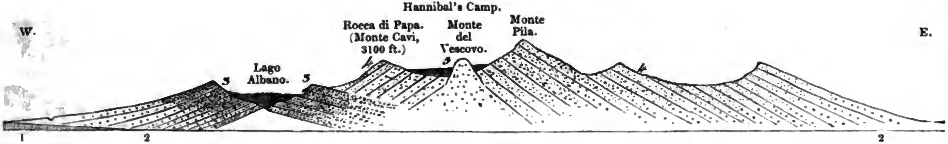
The chief remark I have to make on this rock is, that it seems to have been thrust up through a basin of tertiary subapennine marls, a portion of which it has overflowed and covered, just as many of our Hebridian trap rocks (to use a British illustration) have been protruded through, and have surmounted, our oolitic shales. The Marquis Pareto also describes the tephrine of Radicofani as overlying the tertiary strata; but Pilla believes it is so old, that the subapennine marls were accumulated around it subsequent to its emission. The utter dislocation however of these marls, where they are visible amid the masses of detritus on the slopes of the hills, convinces me, that the igneous rock burst through them at Radicofani, and then overflowed them. There are some appearances as if currents of lava had proceeded from this mountain of Radicofani, but they are soon broken off, and are traceable only in loose dismembered blocks which spread over the slopes, particularly to the south. On descending from the mountain, and after travelling to the opposite bank of the Paglia, we find what I consider to be the same tephrine lava regularly stratified in the escarpment above Ponte Gregoriano, north of Acquapendente, where the Papal States are bounded by Tuscany. The blue subapennine marls, fig. 1 *a*, p. 284, are there well exposed at the base of the cliff, partially covered by a thin coating of yellow sand, fig. 1 *b*, both of them well known in these countries as containing marine shells; and these are immediately and conformably surmounted by an amygdaloid, the concretions of which are as compact and well-filled as any trap-amygdaloid of the Highlands. This is followed by a considerable band of the grey basalt, fig. 1 *c*, or tephrine lava with leucite, on which Acquapendente, like Radicofani,

Fig. 1.—*Section at Acquapendente.*



a. Subapennine marl. *b.* Subapennine sand and pebbles. *c.* Basalt. *d.* Tuff, peperino, puzzuolane, &c.

Fig. 4.—*Section of the Latian Hills.*



1. Subapennine strata. 2. Volcanic tuff of the Campagna. 3. Peperino. 4. Volcanic scoriæ, &c. 5. Lacustrine deposits.

Fig. 5.—*Transverse Section of Rocca Monfina.*

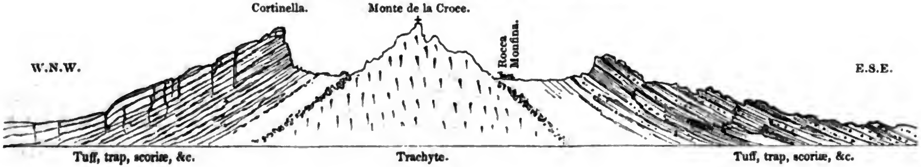
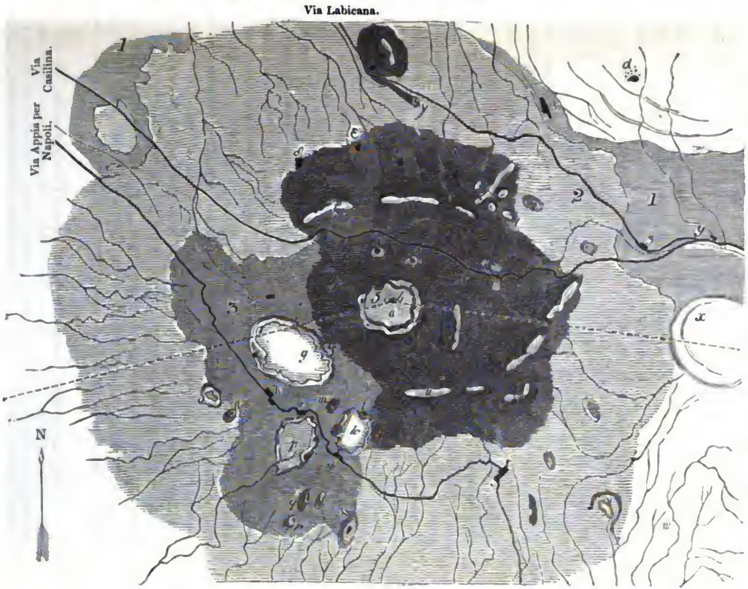


Fig. 3.—*Map of the Latian Hills.*



a. Hannibal's Camp.
b. Monte del Vescovo.
c. Rocca di Papa.
d. Monte Pila.
e. Monte Cava.
f. Palazzolo.
g. Lago Albano.
h. Albano.
i. Ariccia.
j. Genzano.
k. Lago di Nemi.
l. Nemi.
m. Monte Gentile.
n. Monte Savelli.
o. Lago di Giuturna.
p. Valericcia.
q. Monte delle Torri.
r. Monte Giove.
s. Civita Lavinia.
t. Velletri.
u. Monte Artemisio.
v. Lago della Torre.
w. Giulianello.
x. Monte Fortino and Monti dei Volsci (*Hippurite limestone*).
y. Val Montane.
z. Lugnano.

α. Palestrina and Monti degli Ernici (*Hippurite limestone*).
β. Zagarolo.
γ. Colonna.
δ. Frascati.
ε. Tuscolo.
ζ. Monte Porzio.
η. Monte Compatri.
θ. Rocca Priora.
ι. Monte Algido.
κ. Laghetti.
λ. Siani della Molara.
μ. Castello del Tusculo (*Crater*).
ν. Monte delle Tartarughe (*Crater*).

1. Subapennine strata.
2. Volcanic tuff of the Campagna.
3. Peperino.
4. Volcanic scoriæ, &c.
5. Lacustrine deposits.

is built*. The still higher plateau, south of the town, is occupied by great thicknesses of the well-known yellowish tufa of the Campagna, fig. 1 *d*, in the puzzuolana or sandy beds of which many caverns have been excavated. Now, if the "tephrine lava" had happened to contain zeolite instead of leucite, any British geologist might call it a trappean greenstone; and, as it is, there can be no sort of doubt that these Italian earlier volcanic products are as much of subaqueous origin as the blue shelly marine marl and sands which they have traversed, and which they immediately overlie.

In descending from St. Lorenzo to the Lake of Bolsena, the hard leucite rock is seen to contain crystals of pyroxene, hornblende, felspar, and mica. Occasional fragments of secondary Apennine limestone also occur in this rock, but leucite is the dominant mineral. This leucitic rock is encased in a vast thickness of tufaceous, sandy or marly tufa, in parts a peperino, in parts scoriaceous. It is in this feature of being more scoriaceous, and in here and there having a rough or trachytic aspect, that these eruptive rocks, whether basaltic and compact or loose and scoriaceous, more resemble modern lavas and their accompaniments than our British traps. But I observed nothing like a regular quâ-quâ-versal or outward dip from the Lake of Bolsena. The Marquis Pareto, however, who examined the whole circumference, speaks of a slight outward inclination; but even if it be so, on those sides of the lake which I did not examine, there is little or no analogy between such an arrangement and the highly inclined dejections of a subaërial volcano. Pareto's words are only to this effect: "Questi banchi inchinano generalmente più al di fuori, *che verso il centro* della cavità medesima." The hard, compact leucitic rock, which occurs near the summit of the escarpment at the north end of the lake, is again found very little above its level to the south side of the town of Bolsena, where it ranges in devious columnar masses, not unlike many of our prismatic basalts, and is composed of numerous pentagonal and hexagonal columns, the ends of which vary to different angles with the horizon, depending probably upon the outline of the cooling surfaces of the pre-existing materials with which the eruptive lava came in contact. Further southward, *i. e.* on the east bank of the lake, whitish claystones, in parts having a semi-pumiceous or trass-like aspect, alternate with courses of grey-coloured scoriaceous lava. Few persons, who have examined this country, will, I apprehend, be disposed to doubt, that the trachytes of Tuscany and the Papal States are among the oldest of these earlier volcanic rocks. Of this, indeed, the Marquis Pareto has afforded undoubted proof by his description and sections explanatory of the structure of the tract south of Viterbo*. Monte Soriano, for example, which the traveller to Rome from Viterbo leaves upon his left hand, and which rises to about 3300 feet above the sea, is essentially a mass of trachyte, overlapped by these tuffs and scoriaceous accumulations, which encumber the sides of the road at L' Imposta between Viterbo and Ronciglione. These latter deposits only, according to Pareto, could have had an uninterrupted communication with the atmosphere. The priority of the trachyte, or its formation under different conditions, is, as I shall hereafter show, a point of considerable importance in its bearing on the question of the origin of Rocca Monfina in the Neapolitan States.

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* In Brongniart's classification of rocks, the basalt of Radicofani is called "Téphrine pavimenteuse," and is associated both with the lava of Volvic, in Auvergne, and with a production of Monte Nuovo in modern times. And yet nothing can be *geologically* more distinct than the periods of eruption of these three rocks. Again, the basalt under Acquapendente, which geologically, in my opinion, is simply a varied mineral prolongation of a band issuing from the same centre as that of Radicofani, is distinguished as "Téphrine amphigénique," merely because it happens to contain imbedded crystals of amphigène or leucite.—*Classification des Roches*, pp. 118–119.

* For a more special description of the western part of the volcanic region of the Papal States than is offered in my sketch, I refer the reader to a memoir of the Marchese L. Pareto, entitled "Osservazioni Geologiche dal Monte Amiata à Roma." (Extract from the Giornale Arcadico, Roma, 1844.) This author, by an appeal to natural sections, proves that of the volcanic rocks, as distinguished from plutonic, trachyte is the most ancient, and that at points east and south-east of Viterbo, that rock, resting at once on tertiary marine strata, is covered by pumiceous agglomerate and volcanic tuff. All the trachytic masses which I have seen in Italy, conveyed to me the idea that they had issued in a pasty state, so as to form domes and flattened cones, which, traversing the pre-existing strata of subaqueous origin, were *the precursors* of all the other volcanic productions of the peninsula. The numerous varieties of trachyte, its crystals of riaccolite, its lithological divisions into fire-stones, paving-stones, &c., and its metamorphic influence on the contiguous deposits, do not come within my present object. (See the works of P. Savi, Pareto, Pilla, &c.) All the subsequent volcanic products of the Papal States are grouped together by Pareto under the heads of tuff with peperino, and lava with lapilli. He believes that all the tuff with peperino and solid agglomerates were formed and arranged under water, whilst the eruption and fall of the lapilli may have occurred at points in connexion with the atmosphere. He gives a full account of the form and structure of the dejections all around the great cavity of the Lake of Bolsena, and is disposed to think, that its parasitic and crateriform depressions, occupied by smaller lakes, may be craters of elevation. Although no one of these cavities—not even the Lago de Vico—seemed to me to fall into the same category as the extinct true volcanos of Auvergne, still I agree with Pareto, that some of the scoriaceous and pumiceous materials, particularly on the plateau south of Viterbo, were probably ejected into the atmosphere. These have, I admit, so subaërial an aspect, that they may well represent the last operation in a series of volcanic eruptions, which terminated as the grounds rose, by throwing up much matter into the atmosphere. Whilst Pareto believes that the depressions near L' Imposta and the Lake of Vico may have been craters whence the leucitic and hornblendic "tephrine" basalts or lavas flowed, he thinks, as I do, that *by far the greater portion of every* volcanic eruption, even in these Colles Ciminii, was subaqueous. In my opinion, such outbursts as that of Graham's Island would explain all, even the most recent, of the volcanic phænomena in the northern Campagna and the region around Viterbo.

The post-pliocene shelly formations on the coast of Civita Vecchia, which are loaded with numerous fragments of the earlier volcanic rocks of which we are treating, show that these last mentioned were consolidated anterior to the accumulations of that ante-historic sea. This evidence tends also to prove, that although, even at that time, so remote in respect to our day, the mollusca living in the sea were the same as those which now inhabit the Mediterranean, the physical geography of the coast of Italy must have been widely different from its present outline; and that as hills, that are now 300 feet above the sea, were then beneath it, so all the lower countries of the Campagna must have been then under water, whether salt, brackish, or fresh. This point will be again adverted to in treating of the Latian volcanos.

But, if for a moment we were inclined to suppose that such rocks as the tuffs of the Campagna might have been formed under the atmosphere, all doubt would be dispelled by finding them associated with, and covered by great thicknesses of water-worn, pebbly detritus. In short, when we follow these dejections from Monte Fiascone to Viterbo and the lakes of Vico, Baccano, and Bracciano, up to Monte Mario and the gates of Rome, we see that their very uppermost dejections are so intimately associated with the upper subapennine strata charged with marine shells and water-worn rounded pebbles of apennine limestone, that all doubt is dispelled, and we are compelled to conclude that all, or nearly all, such earlier volcanic rocks as I have hitherto alluded to, and which occupy the Campagna, were formed either entirely under the sea, or in that condition of things when the former bottoms of seas were emerging and were covered with brackish or impure lacustrine waters. Many of these rocks may be included in the peperino of Brongniart; and although Brocchi attempted to divide them into stony, as distinguished from granular tuffs, and a third variety that may be called earthy tuff, I quite agree with Pareto, that all such divisions depend on mere local accidents and have no sort of geological bearing. All these rocks, however varied, constitute in fact but one formation, from the farinaceous tuff of Monte Verde, near Rome, to the more solid tuffs and leucite lavas of the Ciminian Hills. I have thus dwelt on the true nature of these rocks, in order to attach what I consider to be the right meaning to the words "craters" and "volcanos," which have found their way into the descriptive hand-books of Italy, and which may lead tourists to fancy that there were formerly many volcanos like Vesuvius and Etna in this region of the Papal States.

Of the older class of volcanic rocks I will now cite a few other examples. The deep ravine near Monte Fiascone exposes on its sides fine sections of rocks, the high antiquity of which in relation to the present condition of things is further indicated by their having afforded the materials for those huge rounded blocks of peperino, &c. which are strewed over the slope extending from Monte Fiascone into the sterile valley north of Viterbo, in which the well-known Bulicami, or hot springs, have their issue. All these blocks were manifestly transported by great aqueous currents*.

It is in the sandy varieties of this group of rocks called panchina, puzzuolano, &c., that far the greater number of the Necropolises of the Etruscans were excavated, as well as the crypts and subterranean sanctuaries of the earlier Christian martyrs and refugees in the environs of Rome. He who visits the site of the ancient Etruscan city of Veii may at once verify this observation; for whilst the fortress stood on the harder rocks (leucite lava, &c.), the tombs of the Necropolis were burrowed out of the softer sandy tuff to the north of the city, which is manifestly a finely laminated subaqueous deposit. In the same way at Volterra, where the rocks are not of igneous origin, but are simply the subapennine clays with yellow sands and sandstone, we see how the Etruscans, building their city on the former, constructed their tombs in the dry and easily worked strata of the latter, the "panchina" of the Italians. Tufaceous dejections and erupted rocks containing leucite similar to those already described, occupy large portions of the Papal Maremma. They are also particularly well developed in that undulating low country which constitutes the north-western part of the Campagna and extends from Monterosi by Nepi to Civita Castellana. The cliffs and deep denudations of the last-mentioned place are very striking, and the right bank of the Tiber near Borghetto is instructive in exhibiting the pebble beds of the upper subapennine period surmounted by leucitic lava, thus unquestionably proving, that this igneous rock was poured out under the waters, whilst still lower down in the valley there are re-aggregated heaps of a later aqueous drift, in which leucitic rocks and the debris of pre-existing pebble beds are all mixed up together; a condition of things in all respects analogous to that which I have described as occurring at Ponte Molle near Rome*.

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* The formation of the great globular concretions of peculiar travertine by these "bulicami" of Viterbo are described in Lyell's 'Principles of Geology,' 7th edit., p. 243.

Again, in passing by Eropete and Castelluccio to Otricoli, pebble beds composed of Apennine limestone are seen distinctly to alternate with volcanic tuff. Associated with these subaqueous volcanic dejections of the Papal States, are travertines which have evidently been formed at different periods. Thus, near Siena, the accompaniments of the volcanic phænomenon are almost confined to a copious evolution of travertine, loaded with coarse angular blocks of younger secondary limestone, occasionally two and three feet in diameter, which are honeycombed throughout and associated with tuff, marl, &c. These masses immediately overlie the subapennine marls and sand, and are covered by lacustrine limestone with *Lymneæ* and *Planorbes*; and this again by sandy loam with land remains and coarse alluvia.

Travertine past and present.—The sequence of strata in the southern parts of Tuscany just mentioned, shows very clearly, that the purely marine condition of the strata under which the subapennine sea-shells were accumulated, gave place gradually to other subaqueous conditions, in which, after many "quasi" volcanic eruptions, accompanied or followed by the formation of much travertine, those conditions were at length terminated by a more purely terrestrial state. Evidences in the Campagna di Roma still more completely sustain this view. Spada and Ponzi have, it is true, found fragments of an older travertine in the tuff of this region†, but they admit, that the *chief* masses of travertine (principally formed under water) are of a date posterior to the earlier volcanic rocks I have been describing. In my former communication‡ I exhibited a diagram showing how the lacustrine travertine of Ponte Molle belongs to that posterior date, and there can be no doubt, that from the period when the lower grounds were still much under brackish or fresh water, and when travertine was formed in broad ancient depressions then occupied by waters which are now reduced to the rivers Tiber and Anio, there has been a more or less continuous formation of travertine. In order, however, to draw a clear distinction between the former energy of nature in producing travertine under conditions different from those which now prevail, let us appeal to Tivoli and its environs. There we have fortunately exact chronometers. There we can compare the enormous ranges of this calcareous deposit which were elaborated long before man could have trodden the soil, with those small additions which have been made by the river Anio since the foundations of the Etruscan and Roman buildings.

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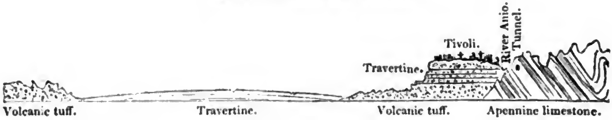
* See Quart. Journ. Geol. Soc. vol. v. p. 296.

† Savi describes a travertine in the Pitigliana in Tuscany, which is covered by volcanic tuff and peperino. Such cases are, however, exceptional, and Pilla admits that the great masses of ancient travertine are of the younger pliocene age.—*Saggio Comparativo dei terreni*, &c. p. 25.

‡ See Quart. Journ. Geol. Soc. vol. v. p. 296, fig. 40.

Fig. 2.—*Section at Tivoli.*



All Tibur or Tivoli, with its temples, stands on what may be designated the ancient travertine, fine lofty scarps of which hang in undulating and contorted layers with their splendid concretions on the flanks of the cretaceous or hippuritic limestones of the Sabine Hills, where not a rill of water now descends, and where consequently not an inch of travertine is ever added. He who would convince himself that the great mass of travertine belongs to a remote antiquity when the configuration of the land was very different from the present, has indeed only to ascend by the small old road from the Villa Adriana to Tivoli. He will there see the truncated edges of that finely laminated rock associated with water-worn pebble beds of a former epoch, when these deposits must either have shelved away from eminences which they now occupy, into waters which then bathed the flanks of the Apennines, or when great barriers, since removed, pent up lakes at higher levels. Again, if he should descend from the walls of Tivoli to the ancient Via Tiburtina, he will successively pass over, first some beds of travertine on the summit, next beds of pebbles chiefly of apennine limestone, and thirdly a great mass of travertine. The whole of these repose distinctly on volcanic tuff, with much disseminated leucite, in which caverns have been excavated, and the lower portions of which have been channeled out by the Teverone or Anio (see fig. 2).

The quarries out of which ancient Rome was in a great part built, situated in the country below, and entirely separated from the Tivoli hills, offer another magnificent proof of the grandeur of the phænomenon which produced the old or ante-historic travertine.

These quarries have been made in one of the faces of a vast flattened dome occupying many square miles, the highest points of which are at some altitude above the river Anio. Charged as it is with fossilized seeds and marsh plants, this travertine was doubtless formed at a period when the waters covered all the lower region of the Campagna, or when very copious mineral springs were in action. It was therefore accumulated when igneous and elevatory action was still acting rifely along all the Italian coast,—that action which had given rise to the earliest volcanic rocks already described, and which, when it had ceased to exhibit its most violent phase, seems to have been followed by a copious evolution of gases and acids, which acting on the limestones of the adjacent Sabine Hills and their outliers that surround this tract, derived therefrom the continuous and rapid additions of old travertine, and saturated therewith very extensive tracts. The small lakes of the Solfatara and Tartaro are now the only remaining vestiges of the former intense energy which produced the wide-spread masses of old travertine. Explained by Davy and chronicled by Lyell, they only acquaint us with the mode of formation on the present minute scale. As no streams or lakes have existed during the historic æra in any portion of the great adjacent low plateau of travertine, with the exception of the pools above mentioned, any more than on the western slopes of the Tivoli Hills, the formation of the enormous breadths of travertine exposed in these localities must be referred to the close of the great subaqueous volcanic epoch which was terminated by the elevation of the Campagna. He who examines the flanks of the Apennines and their recesses, will find, I doubt not, many other masses of travertine equal in extent to those of Tivoli. Such, for example, fell unexpectedly under my own notice as I was returning from Naples by the middle road, where to the north of Ferentino I saw the apennine limestone and superposed macigno covered on their edges by a great breadth of honeycombed, hard, dry travertine, which extended over the broad valley in rough and undulating hillocks occupying many square miles, and surrounded, as near Tivoli, by the volcanic tuff which near Val Montone fills up all the rest of the trough between the Sabine and Latian Hills, and rises to a considerable height on the flanks of the latter.

When we contrast these grand operations of ancient nature with the deposits of existing lakes and rivers, we at once see, that there is the clearest line of separation between them, dependent in fact on great changes in physical geography. Thus, the above-mentioned tract of hilly travertine between the Volscian and Sabine ridges of apennine limestone is separated from all the drainage of the Anio and the Tibur and the Campagna di Roma, by a "divortia aquarum" composed of volcanic tuff. Again, whilst the ancient deposits of Tivoli have taken place where the course of a river, still charged to some extent with lime, may under very different outlines serve to explain the *modus operandi*, here, on the contrary, there is no stream, solfatara, nor lake; a few pebble rivulets, the feeders of the Garigliano, being alone visible at the base of the hills. This travertine tract, then, has also been accumulated towards the close of the earlier volcanic period, and after the tuff of the Campagna had to a great extent assumed its present outline and constituted terra firma and natural barriers.

But to return to Tivoli and there compare the present operations, in the formation of travertine, with those of former days.

We there see, that all the calcareous matter which the river or its Cascatelle have added to these ancient deposits, since the Temple of Vesta and the Villa of Mæcenas were built upon them, is so mere an incrustation, that if it were necessary to estimate the age of the ante-historical or earlier travertine by such a scale, we should have to recede millions of years to account for its dimensions. When we reflect, however, upon what must have been the condition of things when the whole of this coast region was the scene of powerful volcanic activity, there can be no difficulty in imagining how vast quantities of travertine may then have been spread out in a comparatively short time; whilst the limited and slow supply of the modern travertine is perfectly intelligible, now that volcanic action is either entirely dormant, or only exhibits here and there feeble signs of its subterranean existence.

In reference to the enormous dimensions of the old travertines of Tivoli, Sir Charles Lyell has expressed his belief, that they may have been formed in a deep lake, or in lakes similar perchance to one of those which have been let off in the historic period along the upper course of the Anio. But I cannot believe that the lake in which the old travertine of Tibur was formed, could have been in existence during the occupation of Italy by the human race, as my friend leads us to infer by his mention of the discovery of the impression of a cart-wheel in an upper portion of this rock. This circumstance can, it appears to me, be much better accounted for by what has recently occurred at Tivoli, and without connecting the ancient travertine with the works of man.

The river Anio has, as is well known, escaped from the flank of the Apennines for ages, both by a principal channel between the great plateau of travertine on which Tibur or Tivoli has been built, and the adjacent ridge of secondary (cretaceous) limestone, and also by numerous underground currents which find their way through the cavities and recesses of the travertine to issue in the Cascatelle. In fact, the hard impervious cretaceous limestone on the right bank of the stream has been for ever throwing off the waters, and forcing them to undermine the softer old travertine on the left bank, and as the necessary result, a city built on a porous substratum so assailed at high floods, has been subjected to great periodic calamities.

It was to obviate the recurrence of these misfortunes, that the Cavalier Bernini, in the 17th century, opened out a new and straight channel through the eastern portion of the travertine, which carried the chief body of water into the chasms so much admired under the Temple of Vesta, whence it cascaded through the grottoes of Neptune and the Syren down to the lower falls. At length even this remedy proved inefficacious, probably owing to the channels of escape getting choked up by increasing layers of calcareous matter, and during a high flood in 1826 a great calamity occurred. Having risen suddenly to some height above its maximum level, the water, unable to escape, was thrown back so violently against the south-eastern corner of the town above the bridge, that it broke away the travertine cliffs, and with their fall demolished the church of S^{ta} Lucia and thirty-six houses, nearly all the transportable materials of which were hurled down torrentially through the cataracts and falls. In this transport it happened, that some of the largest beams of the church stuck fast in the grotto of the Syren, and one of them in particular still remains like a bone in the gullet of an animal, and will doubtless in due time get buried in travertine, which though formed only a few years ago, is *apparently* subjacent to a great mass of rock, accumulated, I have no doubt, before the Roman æra. As in future ages this beam of a church (and many other materials) may be found lodged or deposited apparently in the body of the travertine, it might be inferred (particularly as the course of the Anio has now been greatly changed) that the church rafters were contemporaneous with the formation of the ancient travertine. In like manner I believe that the cart-wheel alluded to by Sir C. Lyell may have been transported at a comparatively recent date, and was by some such operation wedged into a recess of the older rock.

In truth, the travertine formed only a few years ago cannot easily be distinguished, if at all, from that of the post-pliocene period. Agreeing therefore with Sir C. Lyell, that the greater portion of this calcareous formation was accumulated in lakes, which he admits may have been for the most part anterior to the æra of history, I differ from his inference, that any portion of the lake, in which the old travertine on which Tivoli stands was accumulated, could have been undrained when the cart-wheel in question was deposited. The natural sections which expose the edges of the strata of volcanic tuff, covered by great bands of travertine, in the cliffs far above the Campagna di Roma (see fig. 2, p. 290), must convince us that the physical outline of the region was very different from that which now prevails, when such travertine could have been accumulated in a lake of which we nowhere see the western barriers*.

There can then be little doubt, that all the earlier volcanic rocks of the Campagna di Roma, and the great travertines which accompanied or followed their evolution, were formed under subaqueous conditions. The marine animals of the former sea were associated with and succeeded by spoils of terrestrial life washed down from the adjacent Apennines, which then alone constituted the "terra firma" of Italy, and from the character of some of the youngest of these remains (of which I spoke in my last communication) as well as from the nature of the travertine, we infer that the waters passed from a saline to a freshwater condition. This latter period was, I believe, coæval with part of the younger pliocene deposits of the sea, and the enormous changes in physical outline which have occurred since that time in the south of Italy and Sicily are well known to all, and particularly through the labours of Sir Charles Lyell.

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* The noble and spirited work executed in the Pontificate of Gregory XVI., to prevent all such catastrophes as that of 1826, gives a straight and direct issue to the great body of the Anio, by a magnificent tunnel cut right through the promontory of apennine limestone, called Monte Catillo, which has for so many ages thrown off the waters upon the travertine plateau of Tivoli. Though a capital piece of engineering and highly useful, this work will however assuredly fall under the anathema of all lovers of the picturesque, who never can endure the comparison of the present straight and smooth fall of the chief mass of water with the old upper falls, the beauty of which is now to a great extent destroyed by the loss of two-thirds of the water which formerly rushed down them. Still the grottoes are well-worthy of being visited.

Volcanic Rocks of Latium.—The only apparently valid evidences in favour of the former existence of true subaërial volcanos in the Papal States, are those which occur in the Latian Hills to the south of Rome, where Medici Spada and Ponzi have convinced themselves that such phænomena have prevailed. On examining these hills, I could not, however, embrace the entire view of those authors; for although, from what I shall presently state, there is ground for supposing that a central portion of this tract was a true volcano, it appeared to me that the depressions occupied by the lakes of Albano and Nemi came under the same general category as some of the lakes north of Rome (Bolsena, Baccano, &c.), and were therefore excluded from terrestrial conditions*. Independently of their peculiarity of mineral structure, it is stated by Spada and Ponzi, that all the dejections which slope down from the Alban Hills overlap the tufas of the Campagna. One of the most striking of these is said to terminate in the well-known basaltiform mass at Capo di Bove, or the tower of Cecilia Metella near Rome; but I confess I was unable to observe anything like the continuance of what might be called a *coulée* from the Alban Hills to that classic spot. The rock, it is true, contains melilite and pyroxene, minerals of the Alban or Latian system, together with Wollastonite and pseudo-nepheline. Difficult as it is to trace the continuance of such so-called lava-currents, owing, as I think, to great denudation, erosion, and change of outline subsequent to their emission, the traveller perceives that in proceeding southwards from Rome, he leaves behind him, as Ponzi pointed out to me, those broad sweeps and wide undulations which principally characterize the Campagna, and when about nine miles from the city he mounts on the rapid slopes of the Alban or Latian Hills. In comparing the ground and subsoil on which he then stands with that to which he looks back, he already sees that masses of inclined dejections having a certain community of character radiate from a common centre in the form of great bands. Long, however, before I reached the ascent to Albano or Frascati, occasional and isolated blocks of a very different sort of lava were pointed out to me by Ponzi. These contain crystals of pyroxene, and he supposes that they have been hurled from a quondam volcanic orifice in the Latian Hills (such as the Camp of Hannibal, to which I shall hereafter specially advert), and projected to their present habitats in the Campagna distant ten miles from the supposed source of their origin. I shall, however, endeavour to account for the dispersion of these materials in another manner, before I close my description of these Latian volcanos.

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* In their theoretical profile showing the arrangement of the rock masses in the Campagna of Rome, Spada and Ponzi attempt many subdivisions of the deposits above the subapennine strata. Thus, their lowest lavas are trachyte and tephrine basalt overlaid by the tuffs, scoriæ, lapilli, and puzzuolane of the Campagna. These are all considered submarine; but then they are overlaid by the tufaceous marine limestones and travertines of quaternary age, and are followed by tephrine basalt, sperone, and peperino, all of which are considered terrestrial, as well as the younger group of tuffs, scoriæ, and lapilli of the Latian volcanos. These last have been alone succeeded by the relics of the Mediterranean sea and modern fluviatile and lacustrine deposits.

In ascending from the Campagna to Castel Gandolfo and the Lake of Albano, immense sloping mounds of grey peperino, fig. 3, 3, & fig. 4, 3, 3, are exhibited, in which, in addition to numerous crystals of leucite and occasionally other simple minerals, there are large angular fragments of Apennine limestone, some of which are in a highly altered state, and also portions of pre-existing crystalline rocks, containing mica, pyroxene, garnets, and Hauyne. I confess that I could not see any great geological distinction between the compact leucitic peperino, which occupies the high point on which the convent of the Cappuccini stands, as well as the cliffs around the beautiful, deep, oval-shaped Lake of Albano, and the leucitic rocks of Bolsena and Acquapendente before described; nor can I believe that there was any great difference in their age or in their method of emission. For here, as in the so-called parasitic crater-lakes north of Rome, the high walls or banks of the Lake of Albano are completely unbroken, without the semblance of any gap or opening by which a *coulée* of lava could have flowed. It is true, that about a mile to the south of Albano, and nearly on the same level as that town, a new cut in the road, made in establishing a bridge, has exposed grey leucite lava, overlying unconformably the ordinary reddish tuff of the Campagna; but half a mile further on, at Lariccia, these two rocks are conformably arranged, and the same system and relations continue to Velletri and Cisterna. Now if the red tuff, which is admitted to have been a subaqueous deposit, had been elevated into land before the peperino and grey lava flowed upon it, surely we might expect to see some trace of a terrestrial surface, some dirt-bed with remains of vegetable substances between the two rocks; but such is not the case, and the one is at once incumbent on the other.

In mounting from the outer portion of the circle, or from the level of the rocks which encompass the Lake of Albano to Rocca Papa and Monte Cavi (the culminating point of this cluster of hills, on which the Temple of Jupiter Latialis stood), it seemed to me, that near a little chapel the upper courses of the peperino, or outward fringe of rocks, alternate with, and are finally overlapped by, layers of scoriæ and lapilli of a brownish red colour*. Still higher up, and reaching Rocca Papa, all traces of the peperino vanish, and from thence to the summit of Monte Cavi, about 3100 feet above the sea, the whole mass consists of a portion of that grand scoriaceous and cindery accumulation which forms the circumference of the depression called Hannibal's Camp, fig. 3, 4, and 4, 4, 4. Very different, indeed, from that peperino, which I consider to be subjacent (or formed under different conditions), are those scoriaceous dejections which have, to a great extent, a terrestrial or atmospheric aspect. Here also, in physical outlines, we reach something like an analogy to the phænomena of Auvergne; for we see that one of the faces of the brim which encircles the depression in which Hannibal encamped (*i. e.* to the north-west) is broken down, as expressed in a map of the tract prepared for my use by Professor Ponzi (fig. 3, p. 284). Again, all the rocks surrounding this semicircular cavity bear signs of subaërial volcanicity. Scoriaceous fragments and loose lapilli are arranged in fine laminæ, unlike the great amorphous masses of the Alban peperino, and they are associated with what much resembles portions of *coulées* of lava. I further observed tortuous, rope-shaped coils of scoriæ, like those which so abound at Vesuvius, and spherical and flattened geodes of the same substances. Again, these volcanic dejections are traversed by dikes like those of Somma, the modern analogues to which are even seen in Vesuvius. When, however, we come to judge from the mineral characters of all the associated rocks, there are difficulties in identifying some of them with known subaërial productions. Thus, there are apparently issues of matter which the Italian geologists call tephrine lava, containing calc spar, Gismondine, and pyroxene, and which, but for the difference of the imbedded simple minerals, pointed out to me by Spada, I could not distinguish from those basalts of Radicofani and Acquapendente which were unquestionably formed under the waters. There is also a greenish leucitic rock with crystals of dark pyroxene, together with some olivine. Again, there is a very peculiar lava in these dikes and *coulées* in the form of a roughish, light, and somewhat porous trachytic rock, called 'Asprone' by the country people ('Sperone' of authors), which near Rocca Papa is copiously charged with small garnets. It is this 'Asprone' which is largely quarried as a building-stone in the adjacent hills of Tusculum.

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* Though I came to the conclusion that the scoriaceous lava overlaid the peperino, I beg that my cursory researches may be well tested before they are allowed to prevail against the inferences drawn by local observers. I gather, indeed, that Hoffmann viewed the succession in somewhat the same light as myself; for, although he enters into no details, he explicitly states, that the isolated

In respect to the general relations of Hannibal's Camp, it must be admitted, that as all the scoriaceous accumulations occupy hills from 500 to 700 feet higher than the valley they encircle, and as their strata dip away from it, and also have a broken-down orifice on the north-west, the whole scene, as well as the lithological aspect of the rocks, leads to the belief that this may have been a subaërial volcano. At the same time, if such it has been, the volcanic action must have been of very remote antiquity. In proof of this, the sandy and

mountain, of which Monte Cavi is the highest point, is "probably the only crater in the Papal States from which a perfect volcano or volcanic cone, like that of Vesuvius, still rises up, which has been active *since its emergence from the sea.*" (See Geognostische Beobachtungen durch Italien und Sicilien, von F. Hoffmann. Berlin, 1839, pp. 47, 48.)

marly subsoil of the central depression is seen to be a lacustrine deposit, fig. 3, s, & fig. 4, s, which is charged with *Lymneæ* and *Planorbes*, whether of extinct or living species I could not ascertain. It is, therefore, clear, that if ever Hannibal's Camp were the crater of a true terrestrial volcano, as I believe it may have been, its activity ceased at a very early period, and the depression became in subsequent ages the station of a lake which in its turn was let off, and the ground desiccated, probably ages before the Carthaginian invasion! A remarkable feature in this depression is, that precisely in its centre is a conical hill called 'Monte di Vescovo,' formed of the same volcanic materials as the surrounding margin, the escarpment of which is nearly equidistant from the central mount at all points (see Map, fig. 3, page 284, and section, fig. 4).

Besides the chief central crater or Camp of Hannibal, there are two other parasitic and smaller adjacent craters, one of which is called La Tartaruga, which lie immediately to the south of it, in the valley of La Molara, which separates the group of Hannibal's Camp from the sloping ridges of Tusculum on the north. Whether viewed in nature or on the Map (fig. 3), these smaller craters certainly much resemble some of those in Auvergne, and, like their larger neighbour, they have each broken-down rims on their north-western faces. It is also probable from the nature of the rocks, that the same volcanic matter, which issued in Hannibal's Camp and its parasites, also forced a vent in the Lake of Regillus, and at Colonna on the north, and at Civita Lavinia on the south of this system.

Having already expressed my opinion that the flanking masses of Alban peperino are of higher antiquity than the scoriaceous rocks of Hannibal's Camp and Monte Cavi, I may say another word or two, better to explain why I thus differ in opinion from my friends Spada and Ponzi. These authors suppose, that the peperino was formed upon land by a sort of lateral mud eruption which issued from the side of the great subaërial volcanic vent. They base their inference chiefly on the fact, that some grass-like vegetables have been found within the peperino which have their stalks pressed down conformably with the slope of what they consider to be the former *coulée* of mud in which these vegetables descended; and hence they suppose that the peperino flowed upon *land*. Seeing that these vegetables have not been torrified or carbonized, these authors explain this circumstance, by saying that the mud issuing from the volcano, though hot, was not in a state of fusion. Again, they spoke to me of bones of deer having been found under the ruins of a house at L'Arricia as a proof of terrestrial conditions. But the latter observation had not been verified by their personal inspection when I left Rome, and even if it be in all respects correctly stated, it does not, as it seems to me, establish their case. Masses of matted sedge-like vegetables which grew upon the adjacent Apennines only three or four miles distant, and the bones of deer which fed upon these grasses, may both have been very naturally washed into the waters bathing this coast, at the period when those igneous operations were in activity which I presume gave rise to the solid and massive peperino in the form of subaqueous detritus. This supposition is, indeed, fully confirmed by all the accompanying phænomena in the Campagna around Rome, where skeletons of elephants, rhinoceros, deer, and other quadrupeds are not only found in the subapennine marine strata, but also in the subsequently formed igneous rocks and travertines; and to none of these deposits has any other origin been assigned, than that of accumulation *under water*, whether salt, brackish, or fresh. When I examined the grand and deep quarries of peperino near Marino, and between that place and Albano, and saw their amorphous and solid character, I had no doubt that they were of anterior date to the higher and central scoriaceous eruptions of Monte Cavi, which, as I have stated, alternate with and overlie peperino. If this peperino had been emitted as a lateral outburst of hot mud whilst the central volcano of Hannibal's Camp was active, and had flowed upon ground which had then assumed its present form and terrestrial conditions, surely we should see in it something like a lava formed under the atmosphere, and its surface, if not rugged, would, at all events, be more or less porous and scoriaceous, and not the hard, compact building-stone which it is. I could see no sort of evidence to prove that the peperino of Marino was of a different age from that of Albano; on the contrary, I believe that they are integral parts of one and the same subaqueous matter, ejected under pressure around the roots of a group, whose central cone and crater were rising into the atmosphere.

If then we are to admit, that there is any true analogy between Hannibal's Camp and authenticated subaërial volcanos, we must allow, that the most modern dejections are those which proceeded from the higher crater, whilst most of the great amorphous lateral masses may very well be referred to an anterior period, and to formations accumulated under other conditions.

In viewing the Latian Hills as a whole, I should therefore say, that their flanking cavities, still filled with water, whether cup-shaped like Nemi, or elliptical like Albano, are to a great extent analogous to those of Baccano and Bolsena, north of Rome. I believe that, together with the igneous rocks which form their banks, they were accumulated under more or less aqueous pressure, and never were true subaërial volcanic vents; though they probably were apertures produced by the explosion of heat and gases when all the volcanic materials were under water. On the other hand, the true crateriform depressions of Hannibal's Camp and its parasites were, as I think, the lofty spiracles by which the volcanicity was let off,—viz. when the grounds were emerging, or had partially emerged from the sea, and were attaining their present outlines. The probable result of this last operation in the series of elevations and eruptions might be, that by the rising up of the central volcano the surrounding and preexisting masses would radiate from it and slope down into what is now the adjacent low country, as they now do, and thus be in this sense a crater of elevation. I may further observe, that on inspecting this system of hills I was impressed with the idea, that, whilst its uppermost dejections bore some resemblance to the extinct volcanos of Auvergne, still I could nowhere see any such decisive proofs of terrestrial volcanicity as the French tract affords in its most recent *cheires* or *coulées*, and their direct issue from the broken-down lips of craters. I came away, indeed, under the belief, that the youngest volcanic rocks of Latium were probably formed anterior to the last active volcanos of Auvergne; such, for example, as the Puy de Tartaret, which I formerly examined in company with Sir C. Lyell, and which has subsequently had such decisive proofs of its modernity adduced by my associate*. In other words, I apprehend, that in Latium they formed the last part of a continuous series of active igneous operations, which being submarine and to a great extent subpaludine in its origin, assumed gradually (whilst the land was emerging, or very shortly after its emergence) those intermediary and peculiar features which characterize the upper dejections of the Latian Hills. I would further suggest as highly probable, that whilst the old travertines near Tivoli were accumulating, the Latian eruptive forces spent their last energies as active volcanos. This view is also borne out by the striking mineral distinction between these Latian rocks and those of the Campagna di Roma and the Colles Ciminii north of Rome. The Latian rocks not only contain several simple minerals, above enumerated, but are exempt from the felspar so common in the northern tract. In admitting the value of this distinction (indicated by Monsignore Spada), as respects the younger or true volcanic rocks of Hannibal's Camp, La Tartaruga, and Tusculum, I cannot consent to group in the same category the peperinos and leucitic rocks of Albano and Marino. The mere absence or presence of one or more simple minerals cannot stand in the way of geological phænomena and general physical conditions which indicate that this region was manifestly to a great extent subaqueous all around the Latian volcano when the latter was in activity. If, indeed, we are to appeal to mineral characters, even then I contend, that it is quite impossible to separate the peperino of Marino from that of Albano, or the latter, when coarse-grained, from the leucitic peperino forming the outward dejections of Rocca Monfina, which, as I shall hereafter show, were unquestionably formed under water. Again, though Spada furnished me with specimens of what he called stratified cinder-beds between the banks of the Alban peperino, I ask any unprejudiced person to compare these with other rocks ticketed by the same good mineralogist as tertiary tuffs from the Tre Fontane, and with the feathery light scoria, with crystals of vitreous felspar, and the pumice from near Veii and other places north of Rome, where subaqueous conditions are admitted by him to have prevailed, and then say whether the peperinos from the Ciminian or those from the Latian tract have the most subaërial aspect.

That all these eruptive operations, even the last in Latium, were anterior to the desiccation and elevation of the "quaternary" accumulations of Italian geologists, which fringe the shores of the Papal States in the form of raised beaches, is indeed distinctly proved by the discovery, that the bibulous travertine of that age called "Macco," which occurs at Porto d'Anzo*, imbodies fragments of rocks derived from what I have shown to be the newest portion of the Latian volcanos, and in addition to leucite contains crystals of pyroxene and peridote; minerals which first made their appearance in the volcanic products of that time, and have not been detected in the more ancient tufaceous and igneous rocks of the Campagna. Now, Porto d'Anzo or Antium is about twenty-five miles distant from Hannibal's Camp, and as a volcano of its small size could not be expected to eject solid contents to a distance far beyond that to which Vesuvius now occasionally projects fragments in showers, so we have a right to infer, that when the Latian volcano was in activity, the sea approached very near to its periphery or roots. In this case we should have no difficulty in accounting for the washing away of its materials to the spot where Porto d'Anzo now stands, there to form part of the Mediterranean deposits which were afterwards to be elevated, constituting the raised beaches of "Macco." In like manner I would explain the transport of the huge blocks of the Latian volcanic rocks to the neighbourhood of Rome before adverted to. At all events the facts at Porto d'Anzo are sufficient to prove that the relations of land and water have undergone very great change since the activity of the youngest of the Latian volcanos; and it appears to prevent our extending true terrestrial volcanicity beyond the limited area in this region to which I have attempted to restrict it †.

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* See Quart. Journ. Geol. Soc. Lond. vol. ii. p. 75.

Rocca Monfina.—I now beg to say a few words upon that remarkable volcanic tract, called Rocca Monfina, in the kingdom of Naples, which has been described by several foreign authors ‡, to which Dr.

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* On the authority of Professor Ponzi. The quaternary of some Italian geologists is supposed to have been formed since the habitation of the peninsula by man, but this point is not well established.

† After these pages were written, I learnt that Professor James Forbes had read a memoir on the Latian volcanos before the Royal Society of Edinburgh, on the 29th January 1850. On communicating with him, I find that he differs from me as to the origin of the Lake of Albano and its peperino, and agrees, as far as I understand, in the main with the views of Spada and Ponzi. As Prof. Forbes has paid more attention than myself to the mineral structure of the Alban rocks, my readers must necessarily consult his forthcoming memoir, of which I have only seen the abstract. He thinks that the land was already covered with vegetation when tremendous outbursts forced open the cup-shaped cavities of Albano and Nemi, and that mud eruptions from lateral orifices were poured forth since the ground assumed its present relations and outline (as at Marino). He seems to believe in three periods of peperino and lava dejections, all subaërial. To these views I cannot subscribe, for the reasons adduced in the text. I cannot imagine that the deep lake depressions of Albano and Nemi, with their solid lofty cliffs and unbroken sides, were ever subaërial volcanos. Nothing like these, I would suggest, has ever been formed by volcanos in modern ages: nor do I comprehend how the enormous thick masses of peperino which are opened out in the quarries of Marino, should have issued from the extreme, external, and lower flank of a volcanic group, which, according to the admission of Spada, Ponzi, and Forbes, must have had (and probably, as they say, at the very same time) an unchecked orifice in the great central crater of Hannibal's Camp. I repeat, that it is with diffidence that I oppose this portion of the view of these my friends and contemporaries, but, with my present knowledge, I adhere to the line I have adopted. In considering the chief Latian volcano subaërial we are all agreed.

‡ See *Breislak*, Voy. Phys. et Lithol. dans la Campanie, 1801; *Abich*, Ueber

Daubeny* called the special attention of British geologists, and whose relations were critically discussed by Mr. Horner in his discourse as President of the Geological Society in 1847.

This lofty tract, the interior of which was, as Daubeny has shown, the stronghold of the warlike Aurunci long before Rome had acquired its great power, lies between Sessa on the west and Teano on the east, and derives its present name from a high rock of solid trachyte (Monte della Croce) which rises in the centre of a grand upland crateriform depression, and is about 3300 feet above the sea. This high tract is shut out from the circumjacent low countries or bays in the apennine limestone by a more or less circular ring of eminences of different altitudes, the highest of which, called Monte Cortinella, is nearly as lofty as the central mountain; whilst the others are of much less altitude, being on an average not more than 300 or 400 feet above the upland depression. They constitute, on the whole, a brim or margin surrounding the circular depression, from the centre of which rises the above-mentioned trachytic mountain. These eminences of the margin differ, however, essentially in their composition from that of the central mountain. They consist of tuff, scoriaceous rocks, and peperino with pumiceous or trass-like dejections, whose outward slopes extend on all sides into the surrounding low country, as if radiating from a common centre. In circular arrangement, and even in having a central boss, Rocca Monfina is analogous to Hannibal's Camp in the Latian Hills; but when we compare the two tracts, essential distinctions arise. Thus, the central boss at Hannibal's Camp is of the same composition as the immediately surrounding dejections of Monte Cavi, &c.; whilst at Rocca Monfina the centre and flanks are of such very different structure, that the one must have been formed separately from the other.

Pilla had remarked that the culminating-point of the central mass of trachyte, or the Rocca, is precisely equidistant from all parts of the escarpment of the surrounding dejections†; but he omits to state, and I do not find it noticed in other authors, that portions of the same trachyte protrude in lower bosses between the main mass and the environing brim. This feature, however, I particularly observed to the south of the hamlet of Casa Fredda, where a mount of trachyte occurs upwards of half a mile distant from the slopes of the chief mass of that rock, and consequently near to the surrounding belt of volcanic hills.

The diameter of the crateriform cavity is about two and a half miles,

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die Natur und den Zusammenhang der Vulcanischen Bildungen, 1841; and *Pilla*, Annales des Mines, 1841, and Saggio Comparativo, 1845.

* See Dr. Daubeny's Memoir, Transact. of the Ashmolean Soc. Oxford, 1846; and also printed in the New Edin. Phil. Journal, vol. xli. p. 213. I visited Rocca Monfina from St. Agata and Sessa at the end of February 1848, and passed along its eastern flanks in the following month on my return from Naples to Rome.

† I presume that Pilla could only mean, that the escarpment of the limited portion of the brim called the Cortinella described an arc exactly equidistant in its parts from the summit of the Monte della Croce; but this is very different from the interpretation usually accepted.

and the section, fig. 5, p. 284, gives some idea of the relations of its brim to the central trachyte.

By reference to the section (fig. 5) it will be seen, that however the *summit* of the Monte della Croce be nearly equidistant from any portion of that part of the adjacent brim properly called the "Cortinella" (as insisted on by M. Pilla), the centre of the trachyte is nearly double the distance from the less elevated segments of the brim south and east of the village of Rocca Monfina; and therefore it is, that the occurrence of some trachyte *in situ* which I observed in the intervening valley is of importance in leading us to any sound theoretical inference. At the same time, no clearer geographical proof can be given that the chief mass of the trachytic mountain is not in the centre of the crater, than that in proceeding from Sessa to the town of Rocca Monfina, the traveller having ascended by the chief watercourse on the west by which mills are turned, and having passed through a gorge in the volcanic brim, thence traverses the crater directly from S.S.W. to N.N.E., without touching upon the steep southern face of the Monte della Croce, which he leaves about half a mile on the left hand.

Nothing can be more in contrast than the central trachyte of the Monte della Croce and the dejections which surround the crater and dip away into the surrounding low countries. To a person unaccustomed to trace the transitions between submarine volcanic rocks and those formed in the atmosphere, it would necessarily appear difficult to distinguish some of those dejections which slope down to Toro di Sessa and Sessa (such as the scoriaceous masses with some lapilli) from what are now forming in Vesuvius; but on the other hand, he will, on careful scrutiny, observe that these graduate into, and *alternate with*, hard leucitic rocks and peperino (quarried as millstones) and amygdaloids, both of which are unlike modern productions, and have a porphyritic cast*. The distinctions between these external productions of Rocca Monfina and the modern ejections of Vesuvius are indeed strikingly exhibited in the crystals of leucite, which in the former or more ancient rock range from half an inch to 2½ and 3 inches in diameter, whilst in the showers of Vesuvius they do not exceed the size of peas†. Again, instead of true pumice, he meets with vast mounds of white felspathic aqueously-formed trass, from which the Fiume Bianca and adjacent rivulets have derived so milky a colour and so unwholesome a character, that to improve the health of the population, it was deemed necessary to construct an aqueduct, which conveys the purest water to Sessa from the central dome of hard subcrystalline trachyte in which the springs issue. Independently then of the manifest distinction between the central and external rocks, this fact alone at once indicates their marked difference.

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* In respect to the arrangement of the external volcanic dejections, I cannot admit as a general rule that the leucitic lava caps the trass and tuff, as cited by Dr. Daubeny; for in the ravines above Toro di Sessa, I met with numerous alternations of these rocks, including those passages from the one to the other to which I here advert.

† A copious shower of these small crystals of leucite issued from Vesuvius in 1847, and is described by Professor Scacchi.

In advocating the application of the elevation-crater theory to Rocca Monfina (in common with Abich and Pilla), and in separating the central trachyte from the external accumulations, Dr. Daubeny thus speaks of it:—"A conical mass of rock so considerable, and yet so completely circumscribed within the area of the crater, could only, as it would seem, have been brought into the position which it is seen to occupy, by being heaved up all at once from the interior of the globe whilst in a semi-fluid or pasty state, but not in a condition of actual liquidity." In theorizing upon the effects of such elevation of the trachyte, he says:—"We have before us an agent which would be not only competent to uplift the surrounding strata of tuff, but which must necessarily have done so, if the latter had been at the time of its eruption in a horizontal position; and to suppose these gradually formed by successive showers of loose incoherent materials before the trachytic rock in its centre was produced, seems to imply a forgetfulness of the height which the tuff has attained, and the high angle at which its beds are inclined." Now, in my opinion, every circumstance, lithological and geological, is in favour of the inference, that the central trachyte is of higher antiquity, and was originally formed under different conditions than the surrounding dejections. Abich describes the rock as "trachytic dolerite," or an intermede between trachyte and greenstone, which contains much green augite and brown mica; and when on the spot I could not hesitate for a moment, even judging from mineral characters only, in believing the central trachyte to be the oldest rock of the tract. In parts it has almost the aspect of an old porphyry. Nay, Dr. Daubeny's own description of its external aspect would have led me to this conclusion. "Its surface," says he, "so far from presenting the rugged aspect which *volcanic* rocks usually assume, is so uniformly clothed with vegetation, and in such a state of complete culture, that but for the amphitheatre of hills which encloses the table-land on its summit, the circular form of which betrays the origin of the mountain of which it forms the outer margin, no one could dream from its physiognomy that the whole was of igneous formation."

In drawing his conclusions as to the relative age of this trachyte of Rocca Monfina, the geologist ought necessarily to be guided by the analogy of the succession established in the Papal States, Tuscany, and the adjacent Ponza Isles; and enough has already been cited in respect to the hills around Viterbo, to testify that the trachytic rocks were there either the first- or the deepest-born of all the earlier volcanic products. Their order is shown by positive sections and superposition.

The inference of my friend Dr. Daubeny, that the trachyte is the last formed of the rocks of Rocca Monfina, has the more surprised me when I look to the good explanation he has given of the close relations of trachytes to granites, and consequently their greater distinction, as I should say, from modern subaërial volcanic rocks. He traces that beautiful series of transitions, by which primordial granite has first been converted into trachyte, and *afterwards* into the various kinds of lava which characterize modern volcanos. Putting aside then all analogy, even in Italy, this admission alone seems hostile to the hypothesis, that the trachytic dome of Rocca Monfina should have been heaved up all at once to its present altitude *after* the accumulation of the scoriæ and lava on its flanks.

In recognizing the distinctions between trachytic and basaltic rocks, their isolation and yet connection, Von Buch and Humboldt show that occasionally in Europe, and often in South America, basalt is superposed to trachyte. "Tantôt," says Humboldt, "ce sont de larges coulées de basaltes souvent interrompues et formant des gradins et des plateaux qui sillonnent et recouvrent ce terrain*." According to Brongniart, trachyte is the granite of plutonic rocks, and is almost as much extended over the surface†.

In placing the trachytes immediately after the serpentines, and before all subaërial volcanic rocks, Pilla is in accordance with all the Italian geologists‡. The same author, in his 'Richezza Minerale delle Toscana,' p. 151, includes the trachyte of Monte Amiata and the grey basalt of Radicofani under the term "piroidi," and completely separates them from volcanic rocks. I have no doubt that trachyte has been raised to the surface at different periods; for General La Marmora has shown that the Sardinian trachyte was erupted anterior to the deposition of the subapennine strata. Other trachytes, as in the Euganean Tuscany, the Papal States, and Ponza Isles, are of posterior date, and probably contemporary with the younger granitic rocks of Elba; whilst the trachyte of Ischia alternates with existing marine shells. In regard to Rocca Monfina, Pilla is of opinion that its volcanic dejections were emitted during what he calls the old alluvial (drift or diluvial) period, and were re-aggregated and transported to distant parts by aqueous action§.

Whether we regard the structure of its rocks or their close analogy to similar masses in other parts of the world and in Italy, my conviction is, I repeat, that the trachyte of Rocca Monfina is the oldest rock of the district, and was formed under different conditions from the surrounding dejections, and under much more pressure. But how and when was this mass of trachyte placed in its actual position? For even if the analogy of the Papal States were wanting, I should have the greatest objection to admit that this rock could have been formed under the same conditions as the surrounding loose dejections, much less that it could have been so raised up into the atmosphere.

From my own observation, indeed, I never could see any good grounds for believing with Mr. Poulett Scrope|| (much as I admire and subscribe to his views concerning the true volcanos of Auvergne),

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* Humboldt, Gisement des Roches, p. 335.

† Al. Brongniart, Classification des Roches, p. 116.

‡ See Trattato di Geologià, p. 13.

§ See Saggio Comparativo, p. 10, Pisa, 1845; and "Osservazioni geognostiche sulla parte settentrionale ed orientale della Campania," Annali Civili delle due Sicilie, fasc. vi.

|| See Volcanos of Central France, p. 58 *et passim*.

that the trachytic rocks of the Mont Dore could have been formed under the atmosphere, or under the same conditions as the surrounding and lower craters. The trachytes and even the domites of that region were, I believe, the earliest-formed rocks along that band of eruptive agency, and were in existence before the outburst of true terrestrial volcanicity. These trachytes may have been formed before the region was entirely drained of the great lakes, which we know prevailed in it. The trachytes of the Rhine, the Siebengebirge, of Hungary, of the Ponza Isles, so well described by Mr. Scrope, as well as those of the Papal States, and lastly those of Ischia, whether we judge from their mineral character, the part they have played, or their physical outlines, all convey assurance to my mind that they were accumulated under water. I look upon them therefore as rocks intermediate between those termed plutonic and volcanic; which were accumulated under pressure and at greater depths, whether under water or heaps of other volcanic materials, and were sometimes subsequently heaved up to their present positions. In supposing this manner of formation, even the symmetrically central cone of the Puy de Chopine, so well delineated by Mr. Scrope, may be accounted for. There, as in Rocca Monfina, the central cone of trachyte may have been the result of the last grand eruption, and from its structure and dimensions may have plugged up the whole of the original crater. In the Auvergne case we have only to believe, even if the lands were then desiccated, that the liquefaction of the trachyte took place at some depth, and that when it was raised by the last grand effort towards eruption, the overlying dejections, finding a vent in small craters, were thrown off as a mantle around it.

But to return to Italy. In the northern part of the Papal States the order of superposition would indeed lead us fairly to infer with Pareto, that the trachyte was the first-born of these submarine volcanic products, and was succeeded by the scoriaceous dejections which there overlie it; but if at Rocca Monfina this conical mass should extend downwards, as there is every reason to believe it does, from the discovery of another protrusion of the same rock, so as to occupy a wide base, as expressed by the dotted line (fig. 5), it would in such cases occupy all the crateriform depression, and we could not then picture even to our imagination the source of the supposed subsequent scoriaceous dejections, particularly those of the lofty Cortinella. In other words, the vent would have been plugged up by the emission of the trachyte.

Granting, then, that the uprising has been the last operation, and that the trachyte has been so protruded as to have *raised up* still more, and to have increased the inclination of, the surrounding dejections, it must have been at that time in a solid state. I do not doubt that the circumambient loose materials had been ejected from a great crater previously to the uprising of the trachyte from the same cavity. They may in the first instance have sloped away at angles of 8° or 10°, and have been afterwards in certain parts raised to 20° and 30°, as we now see them.

In reference to the absence of transverse fractures so pointedly argued upon by Mr. Horner*, I have not sufficiently examined the tract to decide affirmatively that the surrounding brim has no break in it which might have been increased, if not produced, by the uprising of a central mass of trachyte; particularly if we are to suppose, that that mass, being of a conical shape, widened so much downwards, as I have supposed, as to plug up all the area of a former grand submarine crater. For the most part, certainly, the external furrows on the surface of the dejections which slope down into the surrounding country are only what might be supposed to result from thousands of years of atmospheric agency; but the chief cavity in the south-western side above Sessa, by which the principal water-course escapes, is certainly so deep and precipitous that it might be supposed to be a rent resulting from strain or fracture. In deciding cases of this nature, however, every geologist knows that the clear data which present themselves in limestone, sandstone, and schists are often wanting in volcanic rocks. But however this may be, neither the gorge alluded to, nor any other aperture, affords traces of a subaërial *coulée* of lava. The eastern side is alone marked by a broad general depression of the brim, which so dies away that the crater may be said to open out to that side by a gradual and undulating slope, leading down into the valley of Teano. But here again we in vain look for anything like a lava-stream, or even the remains of one which issued from a true terrestrial volcano; whilst in the erosion of the hillocks, as in the characters of the surrounding tuff, we recognise only subaqueous action and denudation. My impression therefore is, that the external tufaceous dejections of Rocca Monfina were vomited from a great *submarine* crater, and were in the first instance probably arranged with a certain amount of quâ-quâ-versal dip, some of them acquiring an almost subaërial aspect, by having been projected into the atmosphere before they fell back again into the sea, and that afterwards the activity of this great subaqueous vent was completely stopped up before the terrestrial conditions were completed, by the upheaval of a solid mass of trachyte which either had been formed, or was kept in a state of pasty fusion at some depth. I suggest that this trachyte may have proceeded from the same volcanic centre, which had either been previously in activity, or was continued in activity, at a greater depth, and under either the pressure of water or superincumbent dejections. In a word, Rocca Monfina differs only from the crateriform dejections around Viterbo, in having trachyte placed in the centre of a crater, whilst in these Papal examples that rock is usually a great lateral appendage or back-bone, the formation of which was manifestly either of anterior date, or of subsequent protrusion from a deeper-seated centre.

In adopting this view of the *modus operandi* by which such an apparent crater of elevation was formed, we cannot indeed expect to find the chasm so generally present in atmospheric volcanos, with a lava-current issuing from it. We might, however, look out for a worn-down side resulting from aqueous denudation, and also for such sorts of scoriæ, lapilli, ashes, and pumice as were ejected in the formation of Graham's Island. Now this is just the succession of materials, as far as I can judge, that occurs at Rocca Monfina, the very external folds of its volcanic system being the most scoriaceous and volcanic, whilst the central dome of trachyte has almost the solidity and compactness of a plutonic rock formed under considerable pressure*.

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* See Anniversary Discourse, Quart. Journ. Geol. Soc. vol. iii. p. lxxxiv.

In endeavouring to fix the age of these volcanic operations, we have unluckily no certain criteria or tests to appeal to; for the valleys of the Garigliano on the west, and of Teano on the east, which flank Rocca Monfina, contain, as far as I know, no remnants of deposit with marine or ancient lacustrine remains; but judging from analogy, and from that continuous undulation from this tract into the Phlegræan Fields, I have little doubt that the surrounding tufaceous accumulations are nearly of the same age. But whilst we can attach no exact idea of age to the term "felspathic tuff" of the Phlegræan Fields, there is still a point on which we may rest, viz. that in a general sense all the region between the Bay of Naples and Rocca Monfina, a distance of upwards of thirty miles, and occupying the valleys in the Apennine limestone, both to the east and west of our volcano, is filled up with undulations of earlier volcanic rocks or ancient alluvia, which most authors consider to have been as unquestionably accumulated *under water*, as those of the Campagna di Roma. Now some of the portions of these which flank three sides of the excrescence of Rocca Monfina are unquestionably superior, or of younger age†.

In drawing our conclusions, it is well to remark, that we cannot pretend to determine the period of the upheaval of certain masses of these Neapolitan tuffs near the sea, by consulting the marine strata which alternate with them, even in those which contain shells perfectly identical with those now living in the adjacent Mediterranean. In my last memoir I have shown that species of sea-shells still in being have existed previously to terrestrial species now entirely extinct (see Quart. Journ. Geol. Soc. vol. v. p. 237). And if we thus fail in measuring the relation of previous epochs to the historical æra, by comparison of things marine with things terrestrial, still less ought we to venture to approximate all the diversified subaqueous volcanic operations of the Phlegræan Fields, or the Campagna di Roma, to our historical atmospheric volcanos, by any reasoning from a few species of marine shells only.

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* In a sketch of the relations of the rocks in the kingdom of Naples, M. Pierre de Tchihatcheff gives the following as the ascending order in time of the volcanic productions of that region:—1. Monte Gargano and the eruptions along the Adriatic line; 2. Monte Vulture; 3. Phlegræan Fields; 4. Rocca Monfina; 5. Vesuvius; 6. Monte Nuovo. (Coup d'œil sur la Constitution géologique des provinces méridionales de Royaume de Naples. Berlin, 1842, p. 171 *et seq.*) I suspect my clever Russian friend would not have thus written if he had more leisurely examined the country. Thus, in approximating the dejections of Rocca Monfina to those of Vesuvius, and in thinking that the one was the immediate precursor of the other, he seems never to have seen (at least he makes no allusion to) the great and remarkable central mass of trachyte at Rocca Monfina, for he admits that trachyte is the *oldest* of all the Neapolitan volcanic products. The credulity of M. Breislak, who believed that remains of Roman buildings were found under some of the tuff of Sessa, and the error of Pilla, in stating that sea-shells had been found adherent to the mountain of Rocca Monfina, are now both admitted.

† A letter just received from that able naturalist Professor Scacchi of Naples, dated the 25th of January, acquaints me that in two memoirs recently published by him in the Transactions of the Academy of Sciences of Naples, he has more fully developed his views as to the origin and formation of the tuffs of the Campania. He assures me, that without any doubt these accumulations are *posterior* to the dejections of Rocca Monfina. Although there are no positive proofs of the *submarine* origin of Rocca Monfina, Scacchi agrees with me as to the ancient and subaqueous character of the trachyte of Monte della Croce (which he considers almost a porphyry), that has closed a great volcanic vent, the materials around which were ejected anterior to the formation of the felspathic tuffs of the Campania. In

Conclusion.—In my method of accounting for the origin and present form of the volcanic tract of Rocca Monfina, I shall probably neither satisfy those who contend that it is an elevation-crater, nor those who would explain it by reference to any known example of modern subaërial volcanic action. I do not admit that in this case, tufaceous deposits, once horizontal, were raised by the sudden protrusion into the atmosphere of a dome of trachyte into highly-inclined positions; for I cannot suppose that this was ever the site of a true terrestrial volcano. In the Latian or Alban Hills, however (if my view of the succession of their eruptions be correct), the formation of a subaërial cone and crater may, as it was the last volcanic operation of that tract, be very well supposed to have raised and thrown off the surrounding dejections of previous and subaqueous origin, with more or less of an eccentric dip of slight inclination. In those parts of the Colles Ciminii where there are no central trachytes, as at Rocca Monfina, and no true central volcano of subsequent date, as at Hannibal's Camp, I can see no valid objection to the admission, that some of the strata around the lakes of Bolsena, Baccano, &c., which consist exclusively of stratified igneous products, may have been ejected from these orifices, probably under shallow brackish or lacustrine waters. On the other hand, I can see no reason for doubting that subsequent efforts towards eruption, whether accompanied by upheaval of solid rocks or not, may have operated from the same centre to raise up and throw off still more the surrounding stratiform accumulations. If we deny the possibility of all stratiform quâ-quâ-versal arrangements having either resulted from, or been increased by, upheaval or elevation, when applied to scoriaceous and tufaceous submarine dejections,

respect to some of the dejections which surround the trachyte of Rocca Monfina, M. Scacchi suggests that several of the mounts may have been separate points of eruption, and possibly had not reference to the great central crater. All the trachyte of Ischia, he shows, must have been formed under submarine conditions, as sea-shells alternate with it up to 1500 feet in height. The craters which supplied the materials of the Campi Phlegræi arose, he conceives, in the sea, however their accompanying cones may have been raised into the atmosphere; and those felspathic tuffs of the Campania which are far removed from their original vents, were, he suggests, not formed under the sea, but upon pebble-beds formed by rivers (and great lakes?), after the partial emersion of the land.

merely because the latter have somewhere been emitted from volcanic vents, we should be forced to grant, that the formation of domes, circuses, and valleys of elevation in sedimentary deposits of aqueous origin, has not been occasioned by the action of plutonic heat or its accompanying gaseous forces. It is evident that the *somewhere* whence the volcanic submarine detritus has been derived, may in many cases be hundreds of miles distant from the deposit; since no one can limit the area to which currents will transport light scoriaceous and volcanic dejections.

For my own part, however, I deem it to be impossible to examine the most striking valleys of elevation in our own country, such as Woolhope and the Dudley Hills, and see how the strata of limestone in those beautiful ellipses are the more fissured by transverse cracks, the more they have been strained and bent, and then observe that such ellipses often run parallel to adjacent outbursts of plutonic rocks *which have broken up and thrown off similar strata*, and not be convinced, that such examples do in some measure illustrate the point at issue. Will any other explanation suffice to account for the shape and fractures of the Wren's Nest and the ellipses near Dudley, except that of intumescence due to the powers of heat connected with the vast diffusion of plutonic matter in that tract? I may be excused for asking those English geologists, who may doubt the efficacy of the interpolated igneous rocks to have produced these striking results, to read the chapters I have written on the subject*, and afterwards the memoir of Mr. Blackwell, of Dudley, which delineates the underground play of the igneous matter, and shows how it has powerfully fractured all the submarine strata and given to the Staffordshire coal-field its form and outline. It is scarcely fair to argue against all craters of elevation, because no plutonic or volcanic rocks have been observed to form the central fulcrum of our English valleys of elevation. For, in my mind, the very circumstance that such ellipsoids are so symmetrically eccentric in their dip, is the reason why we should not expect to find any igneous rock within them. It is, I suggest, from the repression of the effort of the heat, steam, and gases to escape upwards along the axes of such ellipsoids of elevation, that their quâquâ-versal arrangement is due. Nor must it be forgotten, that in the very districts so affected, the igneous matter has usually sought an issue (notably, for example, in the Rowley, Malvern, and Abberley Hills) along the edges of the adjacent deposits, probably because it there met with less resistance than in the neighbouring tracts, which deposits have by the same causes been rolled into undulations, or heaved up into rapid anticlinals. In numerous cases, however (and the west flank of the Malvern is a good instance), we see that the eruptive rock has performed the part of raising and even of overturning the strata on its flank.

The observations I made in Italy, and which I again apologise for, as being necessarily imperfect, have thus led me to add a few words to what I have already written† upon the subject, in the hope of modifying the extreme views of the advocates for and against elevation-craters. Although much indebted to M. Leopold von Buch for suggesting the theory, to M. Élie de Beaumont for extending and illustrating it, and to Sir C. Lyell for his efforts to explain all these appearances by reference to causes now visible, still I must express my belief, that the truth which geologists are in quest of lies in neither extreme. I think, indeed, that the day is not distant when it will be admitted, that in some tracts, in which *submarine* volcanic dejections have been very widely diffused and carried to great distances from the orifices of eruption, the strata have since been heaved up eccentrically by the subsequent operation of heat and intumescence, whether accompanied by an actual eruption of molten matter and scoriæ or not. Such then must be considered craters of elevation. On the other hand, in reference to true volcanic *coulées* and detritus, some districts will be shown to abound still in those grand volcanos, which during countless ages have been augmenting their area by materials, which, derived from their own bowels, have been continually added to their flanks.

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* See Silurian System, pp. 480, *et seq.*

† See Silurian System (Valley of Woolhope).

POSTSCRIPT.

On writing to Dr. Daubeny for an explanation of his views, I find that on one essential point his opinion coincides with my own, viz. that the external dejections around Rocca Monfina *have been all formed under water*, perhaps of no great depth,—an opinion which I am glad I have elicited, as the most careful perusal of his memoir, in which he makes no allusion to subaqueous volcanic operations, had led me to draw another inference.

In the present state of geology, I hold it to be of the utmost importance to distinguish in a marked manner between subaqueous and subaërial volcanic action, and to note well, when it is possible, the cases where both operations have been united. It was to bring this point out in relief that the foregoing lines were penned.

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